SEMI-CONVECTIVE FORCED AIR SYSTEM HAVING AMPLIFIED AIR NOZZLES FOR HEATING LOW "E" COATED GLASS

Field of the Invention

The present invention relates to a semi-convective forced air system and method for heating glass sheets for subsequent processing. More particularly, the system and method of the present invention are used for heating low emissivity coated glass (low "e" glass) before tempering.

Background of the Invention

Forced air furnaces for heating glass sheets in preparation for subsequent processing, such as tempering, are known in the art. For example, McMaster U.S. Patent Nos. 4,529,380 and 4,505,671 disclose a glass sheet processing system which includes a heating furnace and a processing station for processing heated glass sheets to provide bending, tempering, bending and tempering, filming, etc. The furnace of U.S. Patent No. 4,592,380 and 4,505,671 comprises an array of gas jets spaced above a conveyor within a heating chamber. The gas jets supply a primary gas flow directed toward the conveyor to provide forced convection heating of the glass sheets as the sheets are conveyed through the heating chamber. The gas jets of McMaster are arranged in linear series perpendicular to the length of the conveyor and the direction of travel of the glass sheets. Each series of jets is connected to a common linear supply manifold or conduit.

Each supply conduit also extends widthwise in the heating furnace, perpendicular to the length of the conveyor. McMaster teaches that the array of gas jet pumps are spaced from each other transversely to the direction of conveyance so as to uniformly heat each conveyed glass sheet over its entire width.

Heating systems such as that described by McMaster appear to provide acceptable results for heating clear glass prior to tempering. Other known systems provide acceptable results for heating coated glass having an emissivity rating greater than about 0.2 prior to tempering. However, manufacturers have now begun to produce coated glass products having emissivity ratings in the range of 0.15-0.04. Prior art heating systems, including the system disclosed in U.S. Patent Nos. 4,592,380 and 4,505,671, do not provide acceptable results for tempering glass having such low emissivity ratings.

Tamglass U.S. Patent No. 5,951,734 discloses a system for heating low "e" glass sheeting, particularly low "e" glass sheeting having an emissivity rating below 0.2. One of the advantages provided by the heating system disclosed in Tamglass U.S. Patent No. 5,951,734 is that it minimizes the problem of "oil-canning" and "bubbling" in glass sheeting caused by not heating the glass sheets uniformly.

Although the heating system disclosed in Tamglass U.S. Patent No. 5,951,734 provides excellent results, it requires longer heating times to heat low "e" glass to the required temperature than the heating times required to heat non-coated glass. Therefore, it would be desirable to provide a system for heating low "e" glass which requires heating times that are shorter than the heating times required in the heating system of Tamglass U.S. Patent

No. 5,951,734 for heating low "e" glass to the required temperature.

Although heating systems that use nozzles to mix hot oven air and compressed air are known, these structures have been unsuccessful for heating low "e" glass. The nozzles of these prior systems produce a very small area of concentrated air flow, which damages the coating on the glass.

Summary of the Invention

It is an object of the invention to provide a semi-convective forced air system for heating glass sheets during a heating cycle for subsequent processing such as tempering.

Another object of the invention is to provide a semi-convective forced air system that is useful for heating low emissivity coated glass sheeting, including low emissivity coated glass sheeting having an emissivity rating below 0.2.

Another object of the invention is to provide a semi-convective forced air system for heating low emissivity coated glass sheeting which requires heating times that are shorter than the heating times required in the heating system disclosed in Tamglass U.S. Patent No. 5,951,734 for heating low emissivity coated glass sheeting.

These and other advantages are obtained by our invention, which is set out below. Our invention includes (1) a semi-convective forced air system for heating glass sheets, including low emissivity coated glass sheeting in general, as well as low emissivity coated glass sheeting having an emissivity rating below 0.2, during a heating cycle for subsequent processing such as tempering, (2) a method of heating glass sheets, including low emissivity coated glass sheeting in general, as well as low emissivity coated glass sheeting having an emissivity rating below 0.2,

using a semi-convective forced air system during a heating cycle for subsequent processing such as tempering, and (3) a nozzle or air injector used in the inventive semi-convective forced air system for mixing and directing a combination of compressed air and oven air toward a glass sheet to convectively heat the glass sheet.

Brief Description of the Drawings

Fig. 1 is a view in cross-section of a semi-convective forced air system constructed in accordance with a preferred embodiment of the invention;

Fig. 2 is a side elevational view of the system shown in Fig. 1;

Fig. 3 is a view in top plan of the furnace11 shown in Figs. 1 and 2 with the top wall of the heating chamber 14 not shown which shows the air manifolds 20, the nozzles 61 mounted thereon, and the conveyor 18;

Fig. 4 is view in elevation showing a support for an air manifold 20;

Figs. 5 is a view in partial cross-section showing nozzles 61 mounted on an air manifold;

Fig. 6 is a cross-sectional view of a nozzle 61;

Fig 7 is a schematic illustration of the control system in accordance with an embodiment of the invention;

Figs. 8a-d are schematic illustrations of arrangements of air manifolds shown relative to glass sheets in a two-zone oven in accordance with a further embodiment of the invention;

Fig. 9 is a view in bottom plan of the insert piece 85;

Fig. 10 is a enlarged view highlighting what is shown in the circle B of Fig. 6;

Fig. 11 shows a view in elevation of a segmented air manifold of an

alternative embodiment of the invention;

Fig. 12 shows a view in top plan of the segmented air manifold of Fig.11; and

Fig. 13 shows an alternative embodiment of the invention in which heating means are provided for heating compressed air;

Detailed Description

Turning to the drawings, there is shown our inventive semi-convective forced air system 10, which is similar in many respects to the semi-convective forced air system shown in Tamglass U.S. Patent No. 5,951,734, which is incorporated herein by reference. The system 10 comprises a furnace or oven 11 having a furnace housing 12, the construction of which is known in the art as taught, for example, by Tamglass U.S. Patent No. 4,390,359, which is incorporated herein by reference. The furnace housing 12 is preferably made of a heat resistant ceramic material. Like the system of Tamglass U.S. Patent No. 5,951,734, the furnace 11 includes a heating chamber 14 in which glass sheets S are heated during a heating cycle in preparation for subsequent processing such as tempering, bending, filming, etc. The furnace 11 includes heating elements 16, such as gas or electric heating elements, on the top and bottom of the heating chamber 14 which provide radiant heat to a work piece located therein.

A conveyor 18 extends lengthwise through the heating chamber 14. The conveyor 18 preferably includes a series of rotatably fixed horizontally extending rolls 19 which are driven in unison to convey a work piece, such as glass sheeting S, through the chamber 14. A conveyor 18 of this type is well known in the art as taught, for example, by Tamglass U.S. Patent No.

4,390,359. Like the system of Tamglass U.S. Patent No. 5,951,734, our new system 10 in a preferred embodiment has a plurality of air manifolds 20 mounted above the conveyor 18 within the heating chamber 14 and connected in fluid communication with a compressed air source 22 preferably located outside the heating chamber 14. The air manifolds 20 are arranged parallel to the length of the conveyor 18.

The compressed air source 22 preferably includes a compressor 23 which is capable of supplying about 17 CFM at about 50 psi, which is the equivalent of about a 10 H.P. compressor for the largest system. The air source also preferably includes a 120 gallon stationary air tank 25. The stationary tank 25 may have an automatic bottom drain 27 which relieves oil and water build-up from the tank 25.

In a preferred embodiment of the invention, each air manifold 20 comprises a pair of elongate tubes 26 connected at one end by a hollow "T" connector 28. The other ends of the elongate tubes 26 are sealed with a cap, plug, or other means.

A plurality of nozzles or air injectors 61 are mounted on each air manifold 20 such that they are in fluid communication with the air manifold 20. Nozzle 61 mixes and directs a combination of compressed air and oven air toward the conveyor 18 to convectively heat a sheet S of glass on the conveyor 18. This supplements the radiant heat provided by the heating elements 16.

The plurality of nozzles 61 on each air manifold 20 are spaced along the length of the air manifold 20, and as shown in the drawings, the nozzles 61 on each air manifold 20 are preferably alternately positioned on opposite sides of the air manifold 20.

In the preferred embodiment shown in the drawings, nozzle 61 has a body 63 comprising a base portion 65 which is connected in series to two extension portions 67 and 69. A compressed air chamber 71 is formed in the body 63, and the compressed air chamber has an outlet port 73. A compressed air inlet means 75 is formed in the body for introducing compressed air into the compressed air chamber 71. The nozzle 61 also includes oven air conduit means or tube 77 that, in the preferred embodiment of the invention shown in the drawings, extends through the body 63 and the compressed air chamber 71 to a location 79 immediately proximate to and downstream of the outlet port 73 of the compressed air chamber 71.

The outlet port 73 of the compressed air chamber 71 is formed by a gap 81 that extends annularly around the outlet end portion 83 of the tube 77 and is located between the outlet end portion 83 of the tube 77 and an insert piece 85 that is mounted in an opening 87 formed in the lower end portion of the nozzle body 63. The insert piece 85 has a bore 89 extending downwardly therethrough for receiving compressed air from the outlet port 73 of the compressed air chamber 71 and oven air from the tube 77. The bore 89 has a first end portion 91 into which compressed air enters from the compressed air chamber 71 through the outlet port 73 of the compressed air chamber 71 and oven air enters from the tube 77 through the outlet end portion 83 of the tube 77, and the bore 89 has a second end portion 93 from which the compressed air and the oven air that enters the bore 89 exits the nozzle 61. After the insert piece 85 is positioned properly in the opening 87 formed in the nozzle body 63 such that the desired width of the gap 81 is obtained, the insert piece 85 is secured in place in the opening 87 with a

screw 94 that extends through a threaded hole 95 in the nozzle body 63.

As best shown in Fig. 10, the tube 77 at its outlet end portion 83 is angled inwardly to form an inwardly angled outer surface portion 96 that is aligned next to the outwardly flaring first end portion 91 of the bore 89 to define the gap 81. Preferably, the width of the gap 81 is between about 0.006 inches and about 0.009 inches.

Preferably, the tube 77 for each nozzle 61 has a length sufficiently long such that the inlet end portion 97 of the tube 77 is located closely to the oven air near a heating element to enable such oven air to be drawn into the tube 77 when the nozzle 61 is in use in the oven.

In a preferred embodiment of the invention, the inlet end portion 97 of the tube 77 of each nozzle 61 is positioned about 1 to 2 inches from the vicinity of the heating elements 16, and the second end portion 98 of the insert piece 85 is located about 6 to 10 inches above the sheet(s) of glass, with 10 inches being most preferred.

Each air manifold 20 includes a supply tube 32 which is connected at one end to the third port of the "T" connector 28 and at the other end to a distribution manifold 34. The distribution manifold 34 is arranged in fluid connection with the compressed air source 22 and distributes compressed air to each of the air manifolds 20.

The system 10 includes a controller 24 which controls the flow of air through each of the plurality of air manifolds 20. The controller 24 selectively restricts or allows a flow of compressed air to each of the air manifolds 20, or rows of manifolds, at predetermined times during the heating cycle to control the heating process and minimize oil canning and bubbling in the glass sheets.

A solenoid valve 36 and a flow meter 38 are arranged in fluid connection between the distribution manifold 34 and each of the air manifolds 20. Each solenoid valve 36 is connected to the controller 24 which selectively opens and closes each solenoid valve 36 at different times during a heating cycle. Each flow meter 38 monitors the volume of air entering the respective air manifolds 20 and is provided with a pressure regulator to set the upper limit of air flow. Preferably, each flow meter 38 comprises a Dwyer Rate Master Flowmeter, model No. RMC-104-BV having ½ NPT connections and is set at a flow rate of 200 standard cubic feet per hour. Preferably, the solenoid valves comprise Asco two way solenoid valves, model No. 8210C94 having ½ NPT connections and 5/8" orifice with a maximum operating pressure differential of 100 psi. The controller 24 is preferably a programmable logic computer which is well known in the art.

A filter/dryer 40, air regulator 42, and solenoid valve 44 are arranged in fluid connection intermediate the compressed air source 22 and the distribution manifold 34. Preferably the filter/dryer 40 comprises a 40 micron filter manufactured by ARO, part number F25242-111 and a coalescing filter manufactured by ARO, part number F25242-311; the air regulator is preferably manufactured by ARO, part number R27241-100 and the pressure gauge is manufactured by ARO, part number 100067; and, the solenoid valve 44 is manufactured by Burkert, part number 453058.

Preferably, the air manifolds 20 having a plurality of nozzles 61 mounted thereon are arranged in banks comprising at least one air manifold 20. Fig. 2 illustrates a preferred embodiment of the invention which comprises one bank of air manifolds 20, and the bank shown in Fig. 2

comprises five rows of air manifolds 20.

Figs. 8A, 8B, 8C, and 8D illustrate schematically several of many alternative preferred embodiments. In Fig. 8A, the air manifolds 20 are arranged in two banks to form a two zone furnace having a first zone Z1 and a second zone Z2. The first bank of air manifolds 20 located in zone Z1 of the furnace of Fig. 8A has three rows of air manifolds 20, and the second zone Z2 has a bank of one air manifold row. Fig. 8B shows six rows of air manifolds 20 in the bank of manifolds located in zone Z1 and a bank of two rows of air manifolds 20 located in Z2 of the furnace. Fig. 8C shows a bank of seven rows of air manifolds 20 positioned in zone Z1 and a bank of three air manifolds 20 in zone Z2. Fig. 8D shows a bank of 5 rows of air manifolds 20 in zone Z1 and a matching bank of 5 rows of air manifolds 20 in zone Z2. In furnaces having more than one heating zone, it is most preferred to provide a bank of manifolds 20 having the same number of rows of manifolds 20 to each zone.

In an alternative embodiment of the invention, as shown in Fig. 13, the compressed air may be heated using heating means 99 for heating the compressed air prior to entry into the air manifolds 20.

Also, in an alternative embodiment of the invention, as shown in Figs. 11 and 12, the air manifolds 20 may be segmented into segments 101, with each segment 101 being connected to the compressed air source 22 via a supply tube 32 connected to the distribution manifold 34. Said segmented manifolds 101 provide the option of firing each segment 101 independently of the others, which allows for more uniform heating of the glass sheet S by firing the air only when the glass sheet S is below a segment 101. In normal operation, the leading and trailing edges of the glass sheet S are hotter than

the center of the glass sheet S because the rolls 19 at the leading and trailing edges of the glass sheet S reheat as it moves over rolls 19 that are not covered by the glass sheet S as it oscillates on the conveyor 18. The rolls 19 near the center of the glass sheet S cool down because the glass sheet S is always in contact with these rolls 19 as the glass sheet S oscillates back and forth on the conveyor 18. By shutting off the air to locations under segments 101 when the glass sheet S is not located under such segments 101, the invention minimizes the risk of over-heating the rolls 19 by convention heating and the invention minimizes compressed air consumption.

In another alternative embodiment of the invention, one or more banks of manifolds 20, the manifolds 20 of which having a plurality of nozzles 61 mounted thereon, also may be positioned in the heating chamber 14 below the conveyor 14 in a manner similar to the positioning of the bank or banks of manifolds 20 having the plurality of nozzles 61 mounted thereon that are positioned above the conveyor 18, except that the nozzles 61 positioned below the conveyor 14 are positioned to direct the combination of oven air and compressed air therefrom upwardly toward the conveyor 14.

The system may be used in a batch type furnace or in a continuous furnace during the heating. In a continuous furnace, the air manifolds 20 would not extend over the full length of the continuous system.

In use, the entire length of selected widthwise portions of the glass sheet S may be convectively heated in a specific sequence by controlling the flow of air to selected air manifolds 20.

In use, a sheet S of glass, which may be a low emissivity coated

glass, to be heated in preparation for subsequent processing, such as tempering, is loaded onto the conveyor 18 and oriented such that the lengthwise edge of the glass sheet S is parallel to the length of the conveyor 18. The glass sheet S is then conveyed by the conveyor 18 into the heating chamber 14 of the furnace 11, where it is convectively heated over entire lengths of selected widthwise portions of the glass sheet S by creating a flow of heated air onto the selected widthwise portions of the glass sheet S using a plurality of nozzles 61 which are mounted in the heating chamber 14 of the furnace 11. The nozzles 61 mix and direct a combination of compressed air and oven air onto the glass sheet S. Oven air is drawn into and through the tube 77 and then into the bore 89 in the insert piece 85 in response to compressed air moving through the gap 81, which is formed between the outlet end portion 83 of the tube 77 and the insert piece 85 mounted in the opening 87 formed in the lower end portion of the nozzle body 63, and into the bore 89, is mixed with the compressed air in the bore 89, and is expelled from the nozzle 61 from the second end portion 93 of the bore 89.

Preferably, the oven air is being drawn by the nozzle 61 from a location close to a heating element 16 in the heating chamber 14.

Advantages

In accordance with the system and method of the present invention, heat is uniformly applied over the entire length of selected widthwise portions of the glass sheet to reduce or eliminate oil canning and bubbling.

Our inventive nozzle 61 reduces the need for outside heaters for heating the compressed air since our inventive nozzle permits the use of about 6 times more oven air for use in convection heating as compared to

prior art furances that use nozzles. Accordingly, our new invention permits the circulation of more air by using less ingested compressed air because the nozzles 61 act as an amplifier to pull in about 6 times more oven air than prior art nozzles. So where old nozzles produce one cfm, our new nozzle constructed in accordance with the invention produces 5 times that but with only one cfm going into it. Accordingly, we are getting 5 cfm worth of heated air down to the surface of the glass sheet S as compared to only 1 cfm worth of heated air produced by the prior art nozzles.

Once the nozzles of the invention are heated up to operational temperatures, a change in temperature of plus or minus 50 degrees does not really effect the way that the nozzle works, which is an advantage over prior art nozzles which seem to be more affected by temperature variations.